# Reservoir Characterization of Bassein Formation in Mukta Field, Western Offshore Basin, India*

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## Abstract

Mukta field, located in the Heera-Panna-Bassein (HPB) block in the western offshore basin of India, was discovered in 1981 by ONGC based on 2D seismic data. The field came into production in 1991 from the eastern part through the MA platform. The field was awarded to JVs in 1995 first to ENRON and later on taken by BG in 2002.

The Middle Eocene to Late Oligocene limestone reservoirs of the Bassein Formation deposited over the Panna clastic (Paleocene - Early Eocene) are the major targets as they were proven to be productive since discovery. The Bassein reservoir is the main pay horizon which has been further divided into three distinct units namely Bassein Upper, Middle and Lower (BU, BM and BL) separated by intervening tight zones (TZ3&TZ2).

Seismic interpretation of newly acquired 3D data has brought out the new structural styles along with the identification of fault patterns in the entire seismic cube of Mukta field. Acoustic impedance derived from seismic inversion studies has been used as a secondary variable to condition the properties (PHIT) and has been co-simulated by co-located co-kriging. Petrophysical evaluation has been carried out on the processed logs of all available wells, core studies of few key wells and reservoir parameter has been fixed based on few well test data. Poro-perm relation has been generated with limited core data and has been used for permeability modeling. Saturation height function from FWL has been used for creating water saturation from MB-1 core data. Based on these studies the 3D Geocellular model has been attempted for proper characterization of heterogeneities (vertical and horizontal) of Bassein Pay.

Reservoir in the Bassein B has been characterized and sweet spots in the entire field have been identified for exploitation of locked hydrocarbons. The potential of three hydrodynamically separated reservoir viz. B Upper, Middle and Lower has been assessed. The static model has been used for simulation purpose to plan the development strategy within the field.

## Introduction

The Mukta field is located to the west of the Panna Field and is separated from it by a syncline (Figure 1). The giant Bombay-High field lies to the west of Mukta. The Mukta Block is 777 $km^2$ in area and has an average water depth of 65 meters. The main production from the

Mukta block is from the three stacked oil pools in the Bassein B limestone (Upper, Middle, Lower) at the MA platform. Gas is also present in the Bassein A Zone and the Panna Formation (Figure 2). The B57 structure comprising the MA, MB, MC and MD sectors is a basement high which plunges to the southwest and spills towards Panna in the east (Figure 3). These sectors have been demarcated based on the limit of the pool defined by well tests, contacts and pressure data. Recently, the well MB-2 has been found to be hydrocarbon bearing in Bassein B Middle and Upper reservoirs as depicted by log signature and MDT/mini DST. On the western part of the field, two more discoveries comprising B-19 and B-126 structures have been identified and a number of E&A wells drilled on these structures turned out to be hydrocarbon bearing from the Bassein reservoirs. However, the focus has been on the eastern side of the field for the exploitation of oil and gas in the first phase of development by installing the MA platform in 1991. The MB high is a smaller independent closure located to the SW of the MA platform and is the focus area for near future development.

The present paper deals with the reservoir characterization of Bassein B and A limestone, which are the main pays in this field. The productivity of these reservoirs is quite poor and the main reason attributed for the poor performance is due to poor reservoir properties.

## Present Studies

As of the date of this study, 49 wells have been drilled in the field with very poor primary recovery as the field has produced 15 MMBO oil and 54 BCF of gas so far over 20 years of production period from the lone platform at MA. With an objective to study the feasibility of exploiting the untapped hydrocarbons in other parts of the field, a Geocellular model has been attempted as an input to reservoir simulation studies.

### Reservoir Geology

Each of the principal reservoir units (A, B-Upper, Middle and Lower) has been further subdivided into four zones stratigraphically to better characterize the reservoir. Bassein limestone was deposited as inner ramp to mid ramp deposits in a shallow marine environment with a cyclic depositional trend. Because of the low depositional gradients over the field, the facies pattern is effectively uniform in the reservoir units.

The average thickness of A zone is about 50 m. The average porosity is in the range of 10%. This is mainly a gas reservoir with a thin oil column. The Bassein B-Upper reservoir is typically 40-50 m thick. The upper surface of the Bassein B-Upper reservoir is the regional Middle Eocene unconformity surface. Log porosity ranges from 10-16% (average 13%) in most of the wells. The Bassein B Middle Zone has typically 80 m average thickness. Porosity ranges from 10-16% in the different sub layers of B Middle. Bassein Lower unit rests on the Basal Clastics and is overlain by tight zone TZ2. The average gross thickness of B-Lower unit is about 85m. The upper part of this reservoir exhibits the best porosity development (11%). This reservoir is highly fractured in most of the field as suggested by the production performance from MA area.

### Seismic Interpretation

Newly acquired 3D seismic data has been used for recent interpretations. The horizons mapped include top of Panna Formation, TZ-3, A-zone, Alternations and few shallow horizons (Figure 4). Vertical to sub-vertical faults have also been mapped in the Mukta area and most of these faults extend from the Deccan top to the Alternations. Inversion of seismic data has been attempted in-house to extract porosity from the new 3D volume and then conditioned with the well data. It is observed that negative correlation exists between the porosity and the acoustic impedance as depicted in Figure 5.

### Fluid Distribution

Understanding the fluid distribution is one of the most difficult /challenging problems in the field as the fluids do not seem to be distributed uniformly and these seem to defy accepted concepts. Oil down to situation prevails in most of the drilled wells and varies in different parts of the field; hence, numbers of contacts are observed in the wells. Long transition zones, variable oil-water contacts, oil pool limits vis-à-vis structural definition and drastic areal porosity changes are the key issues in the field.

## Geomodel

The main objective of the Geomodel of Mukta field was to prepare a fine-scale geocellular model to better characterize the reservoirs in Mukta and to assess the hydrocarbon potentialities of the Bassein reservoirs. Generation of Geocellular model involved the following steps:

- Generation of structural model
- Generation of modeling grid
- Upscaling of well logs to the grid resolution(Blocking)
- Petrophysical Modeling

The interpreted surfaces (Alternation, A, TZ3 and Panna) and faults mapped in seismic interpretations have been taken for building the structural model in Roxar RMS. A stratigraphic framework has been created by amalgamating seismic interpreted horizons, geologically modeled isochores, and fault models for generation of intervening surfaces of other reservoir units (Figure 6).

A modeling grid of 100*100 m with 144 layers is constructed giving rise to about 8.5 million cells. The vertical resolution of the layers range 1.6-2.3 m in Bassein B Zone. The well data has been scaled up (blocked) to the resolution of the 3D grid layout. In this model, blocking is done for PHIE, PHIT, VSHALE and ZONELOG.

## Petrophysical Modeling

The correlation of PHIT with acoustic impedance (AI) derived from the seismic inversion study has been used and the correlation values from these cross plots have been used in modeling. The AI has then been co-simulated with PHIE, PHIT and VSHAL by co-located co-kriging. PHIE extracted from model has been compared with the processed logs in B57 representative wells and a good match is seen between the two (Figure 7). Lateral and vertical distribution of PHIE has been shown in the cross sections in Figure 8.

Porosity-permeability relationship from available core data (RCA/SCAL) of MB-1 and MD-1 is used to model permeability. Poro-perm relation so derived from core studies has been used for population of permeability (Figure 9) based on the AI conditioned porosity on each cell.

The J function was used to predict saturation trends in well MB-1. Capillary pressure measurements are performed on each core plug and then converted to J values for each sample and plotted against saturation. A fourth order equation has been estimated to show the relation of saturation with calculated J function and the same has been used in Geomodel for the population across the field. Comparison of model saturation overlaid on the log saturation is shown in Figure10 and the water saturation across the field is shown in the Figure 11.

$$SWN = 0.4079J^4 - 6.3055J^3 + 35.184J^2 - 86.496J + 99.641$$

## Discussion

Bassein B reservoir is around 200-250 meter thick in Mukta field and is subdivided into three hydrodnamically-separated reservoirs. The reservoir heterogeneity has been defined by the Geocellular model, which depicts vertical and lateral variation of reservoir properties in term of their petrophysical parameters viz. porosity, permeability and water saturation. Acoustic impedance derived from seismic inversion studies has been conditioned with porosity and has been populated by co-located co-kriging. The log derived and model based properties depicts good match and validates the Geomodel. The distribution of these properties located in the favourable structural position has been identified. The static model was exported to RE and dynamic model has been prepared by simulation study.

## Acknowledgments

The authors are thankful to BG Group and its JV partners (ONGC and Reliance Industries Ltd.) for providing necessary permission to publish this work on Mukta.

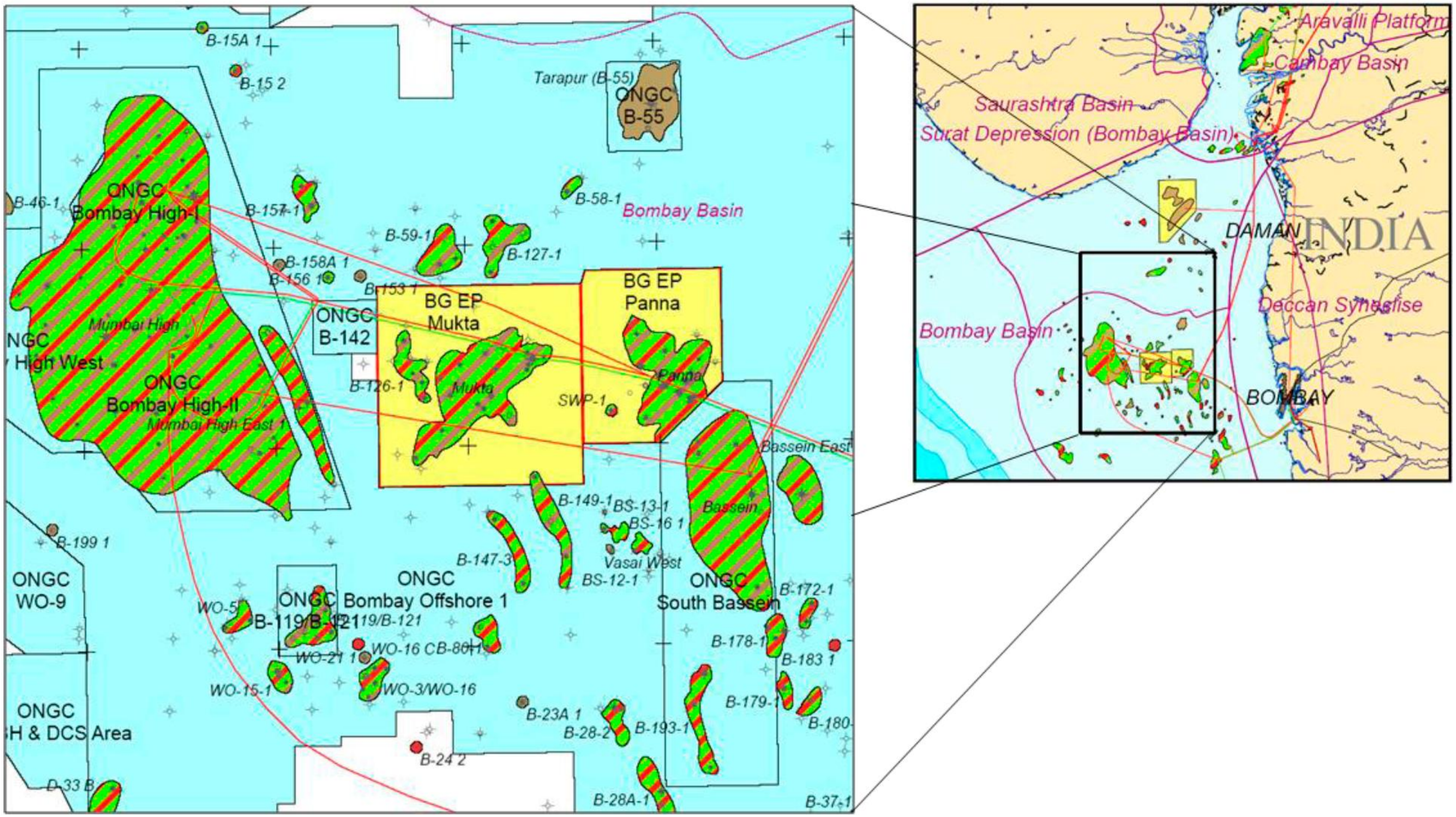

Figure 1. Location map of Panna-Mukta Fields in Western Offshore Basin.

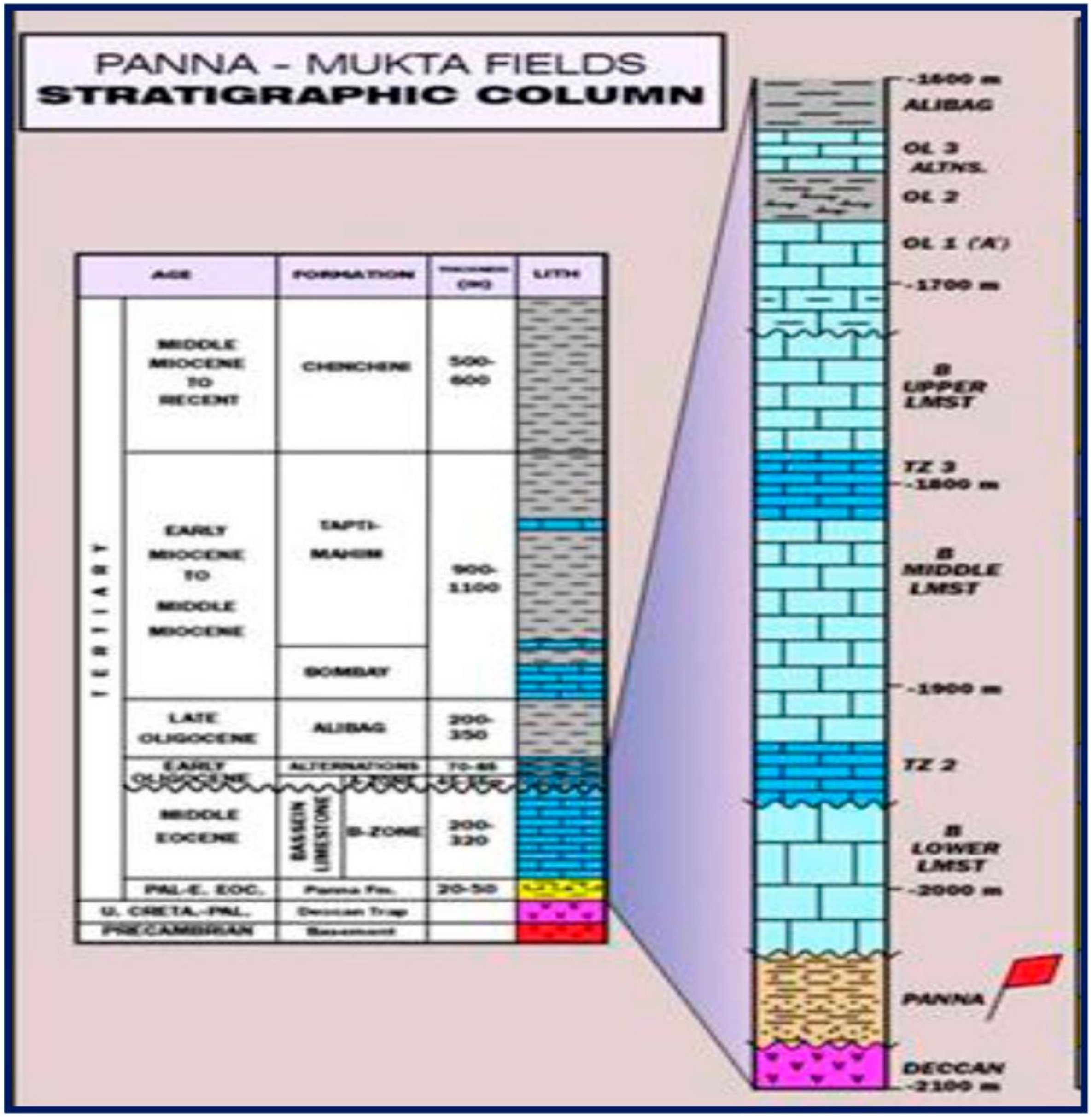

Figure 2. Generalized Stratigraphy of Panna-Mukta Area.

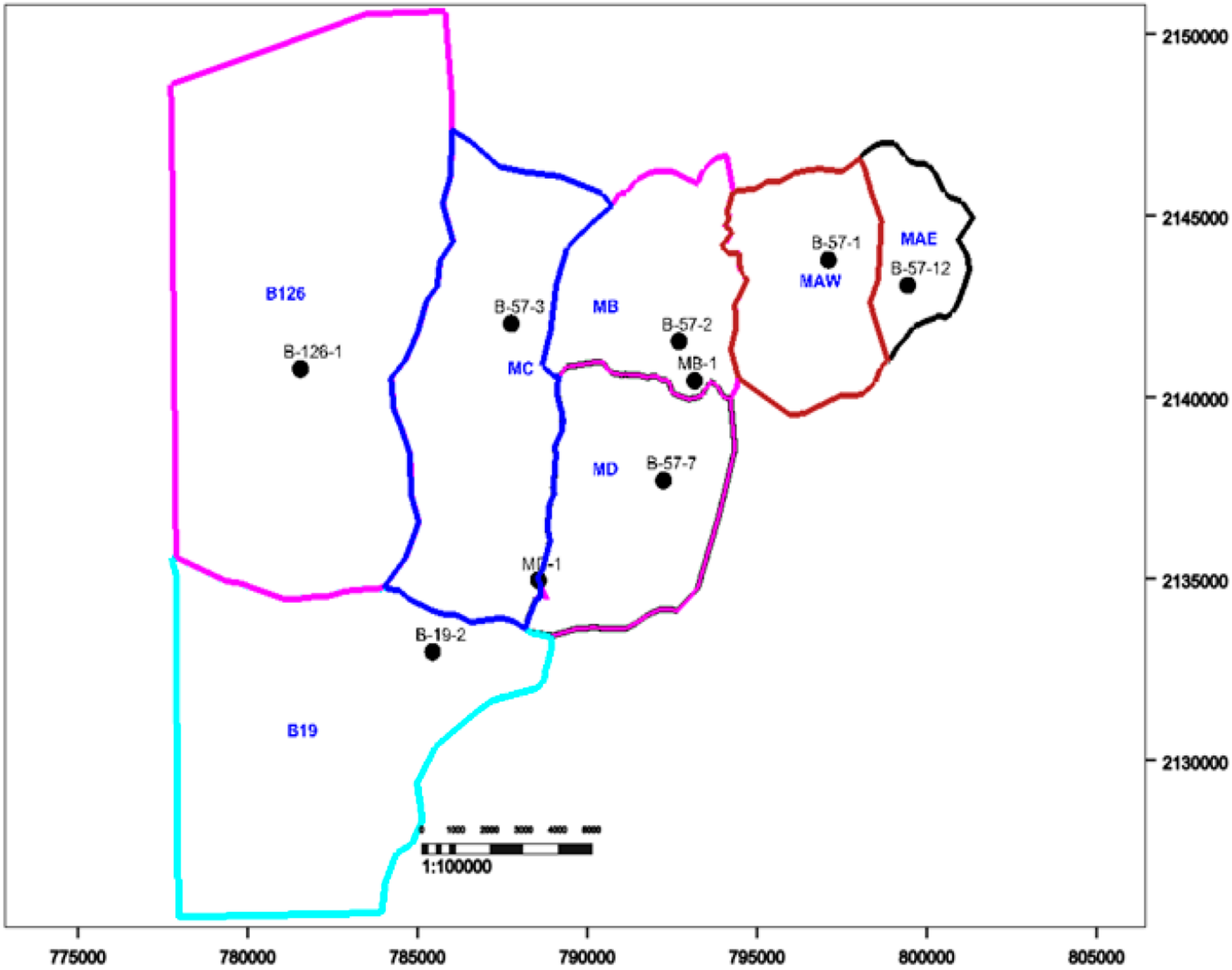

Figure 3. Various sectors of Mukta Field.

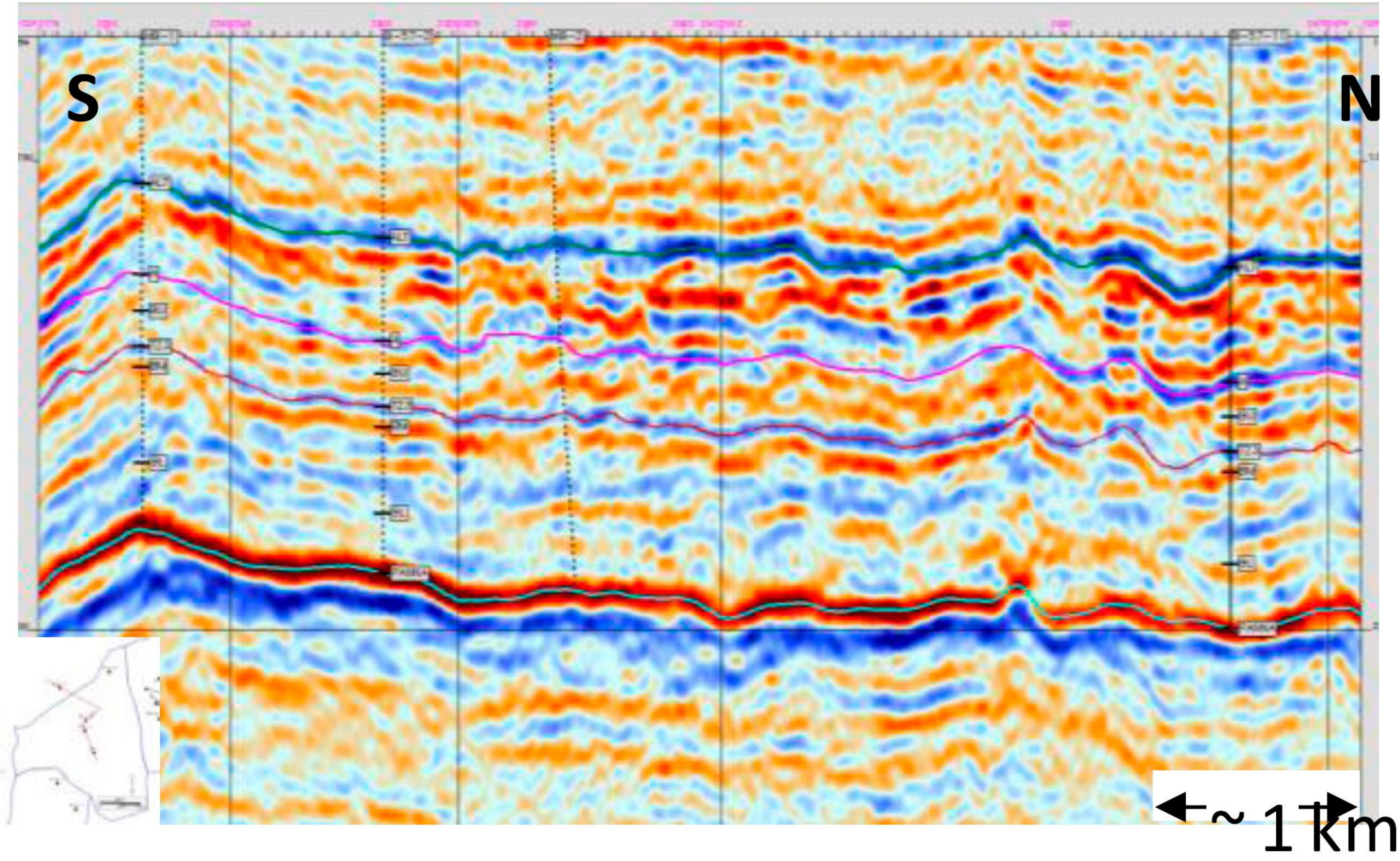

Figure 4. Representative seismic line through the MB development area.

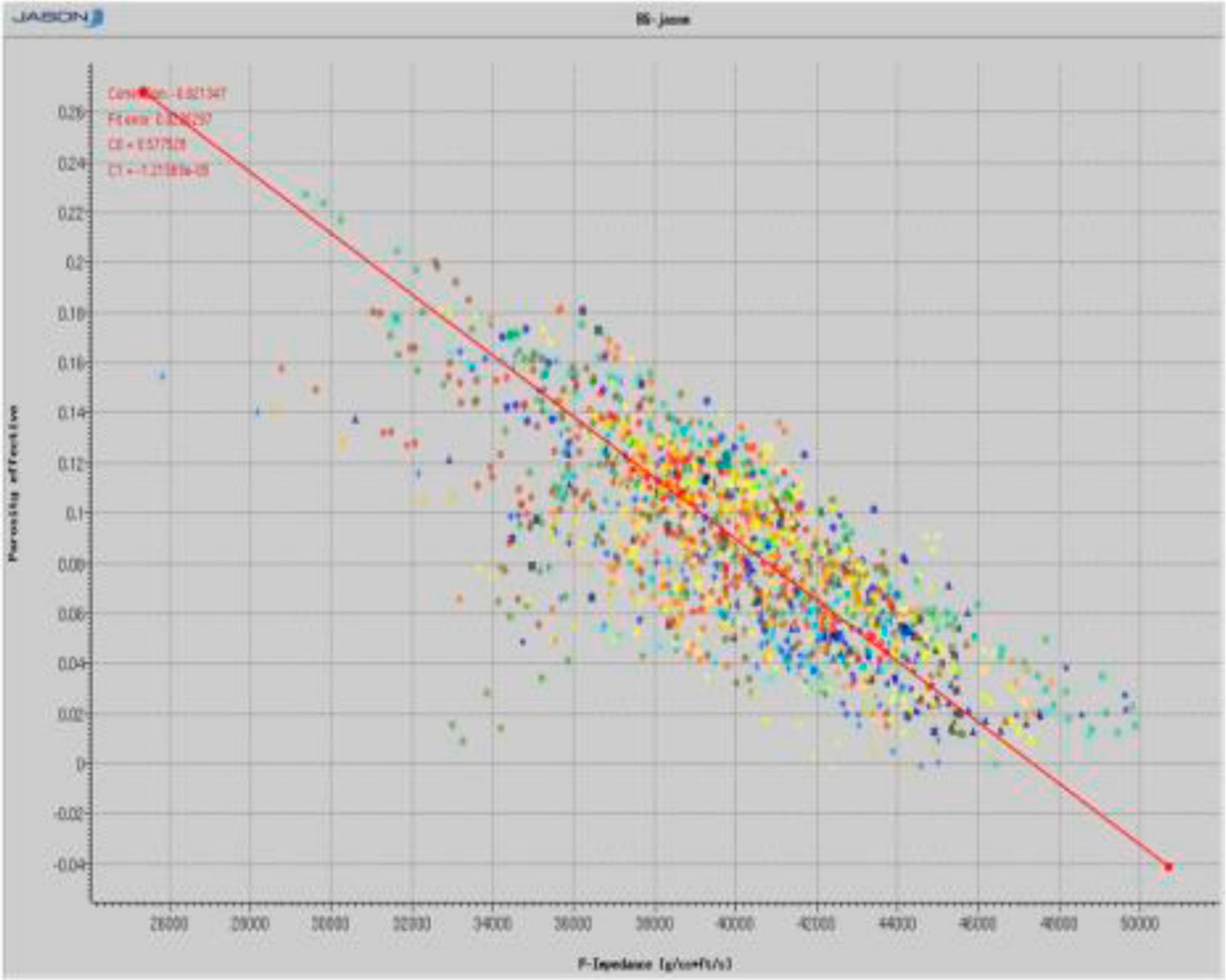

Figure 5. Acoustic Impedance vs. PHIT in BU.

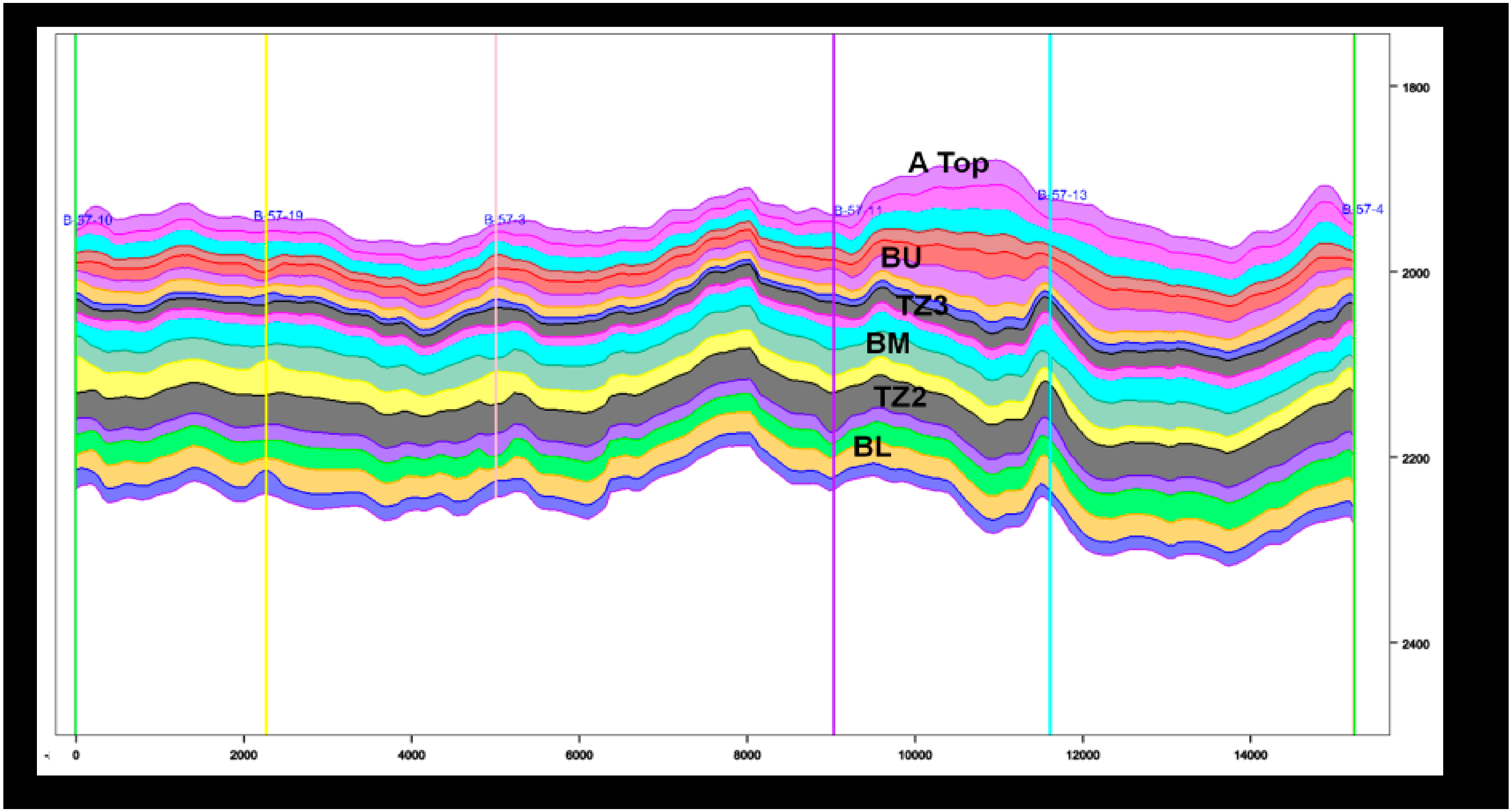

Figure 6. Sub zonation in the Mukta Model between Atop to Panna Top.

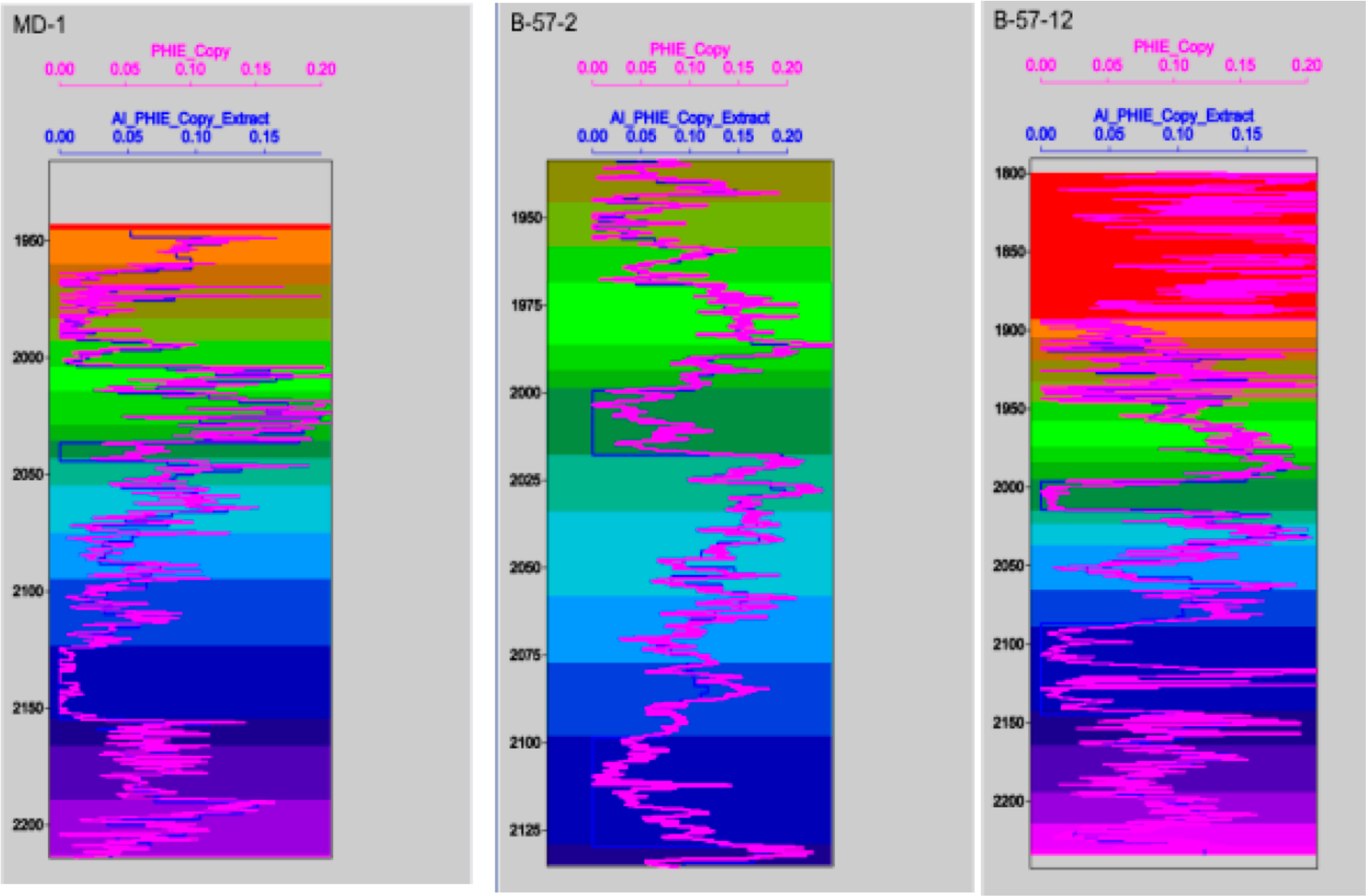

Figure 7. Comparison of Log Porosity with the Model Porosity.

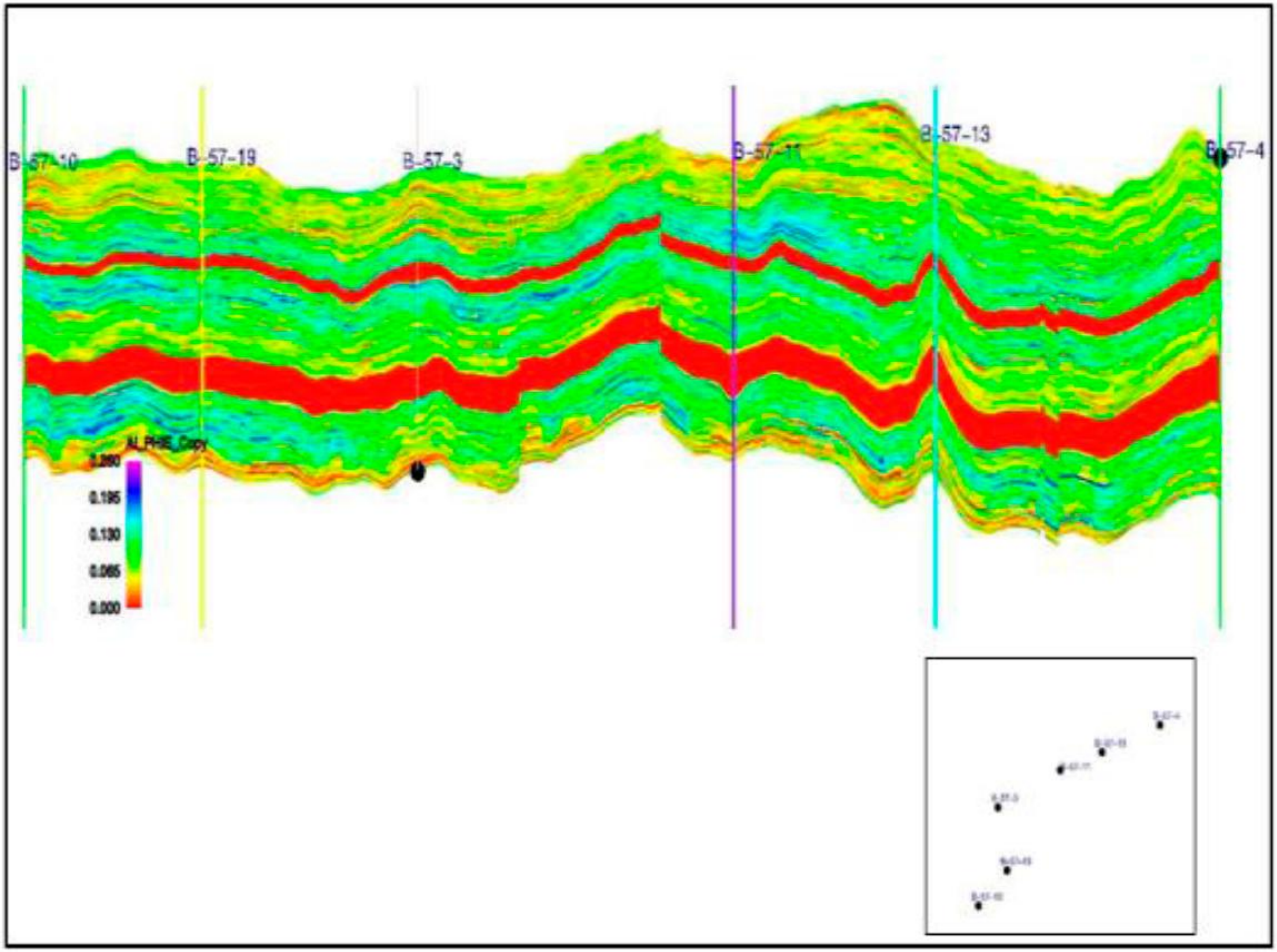

Figure 8. Effective Porosity (PHIE) Distribution across the field.

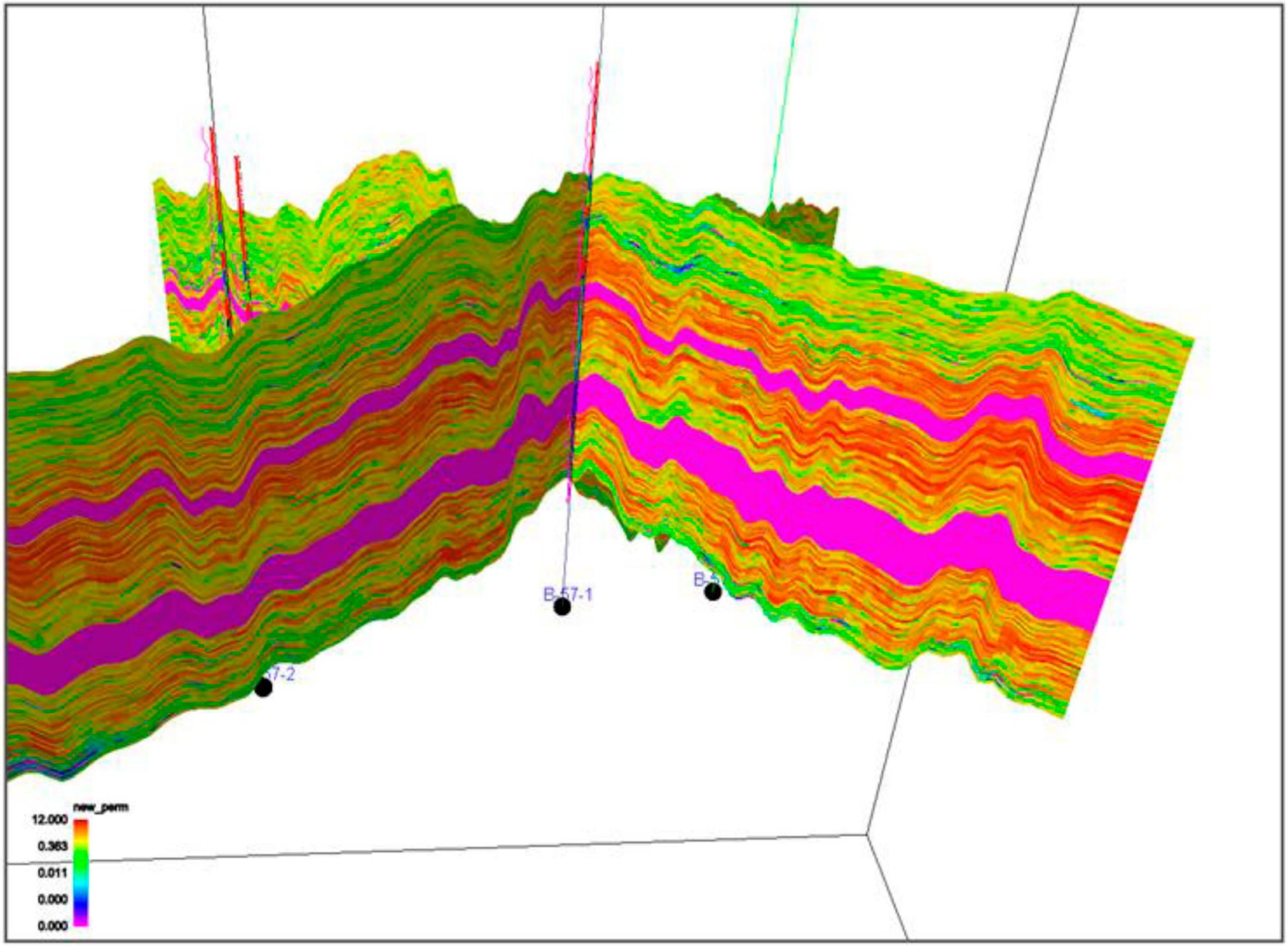

Figure 9. Permeability distributions.

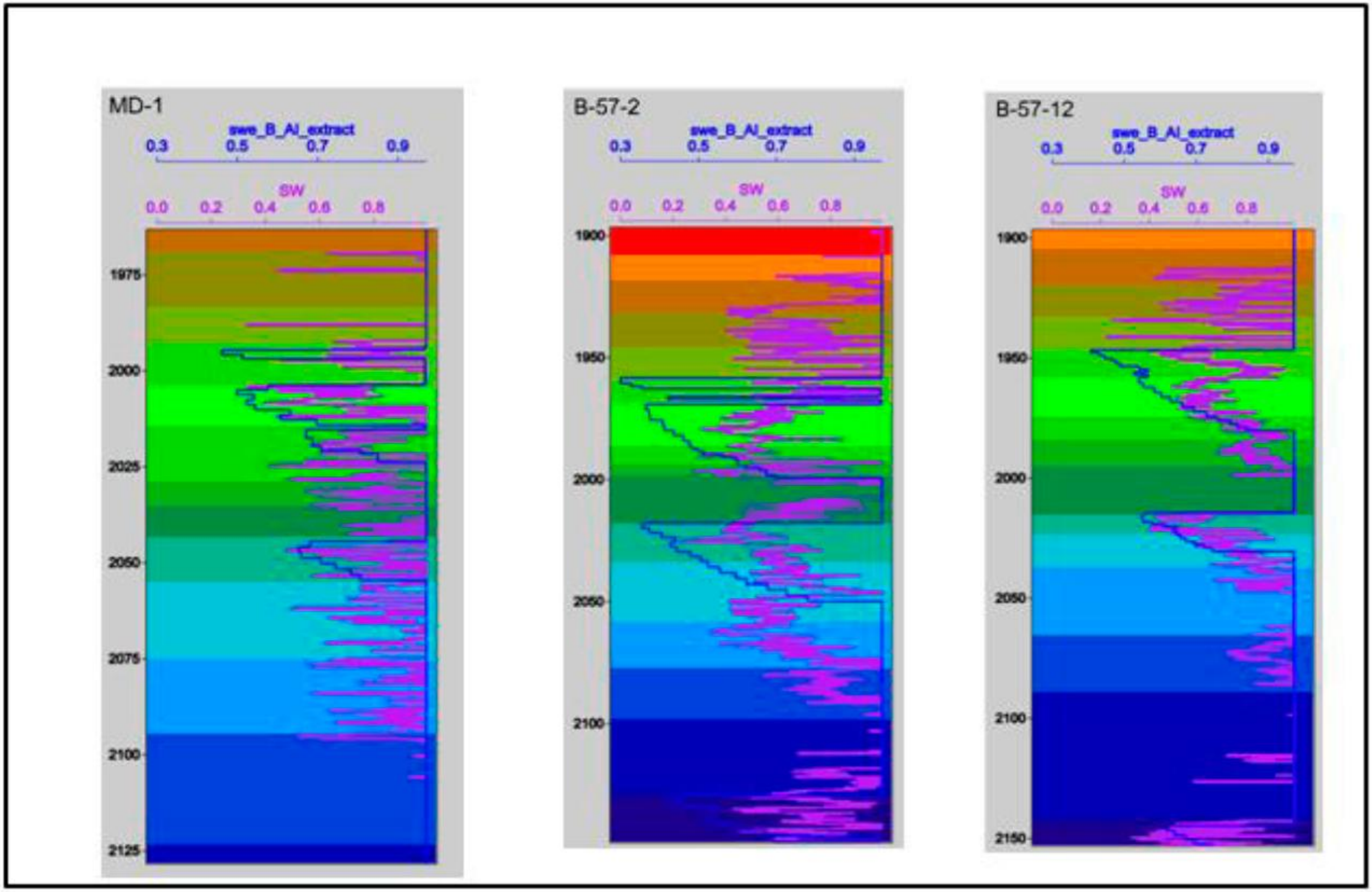

Figure 10. Comparison of Log Saturation with the Model Saturation.

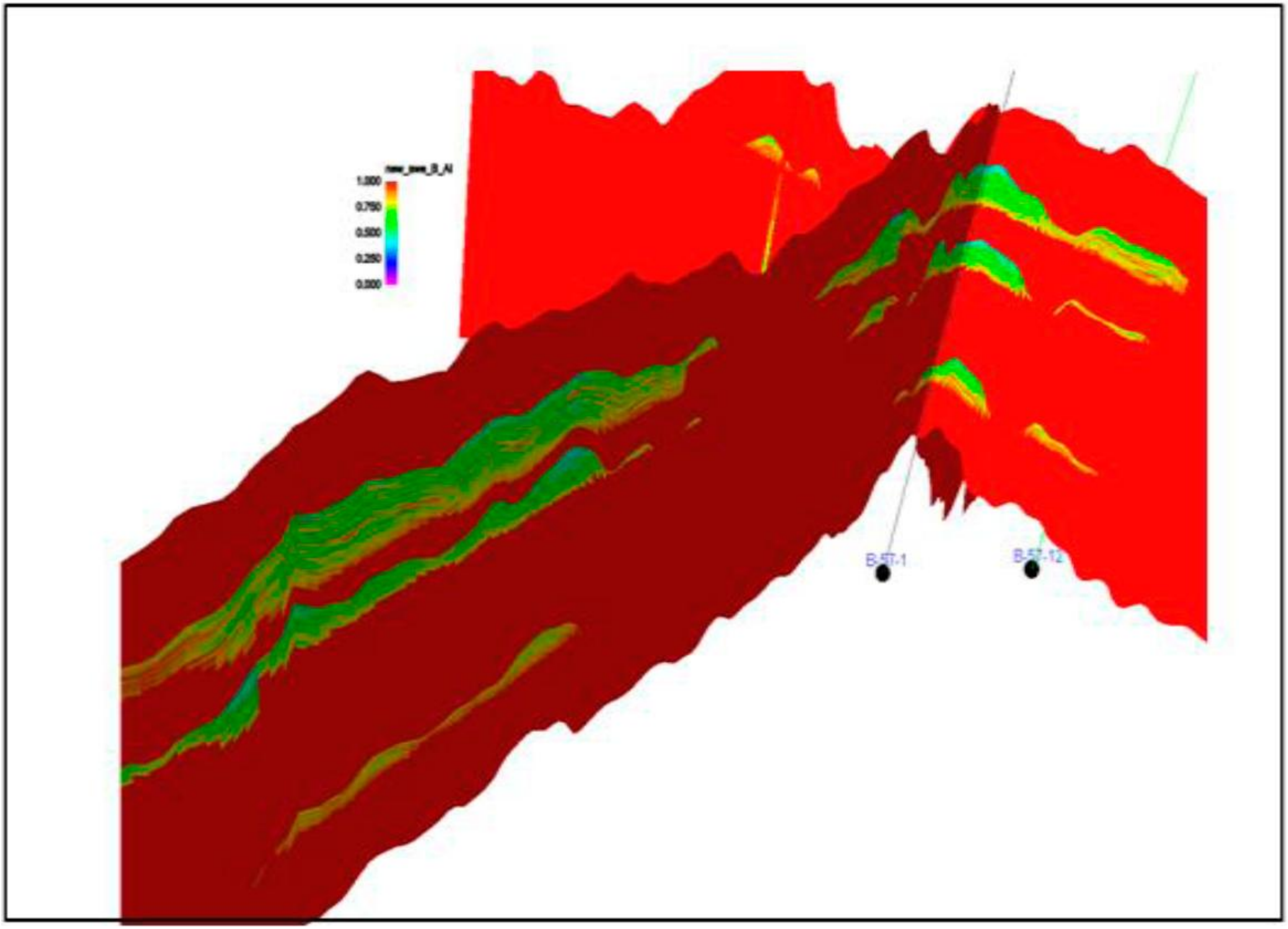

Figure 11. Water Saturation Distribution.